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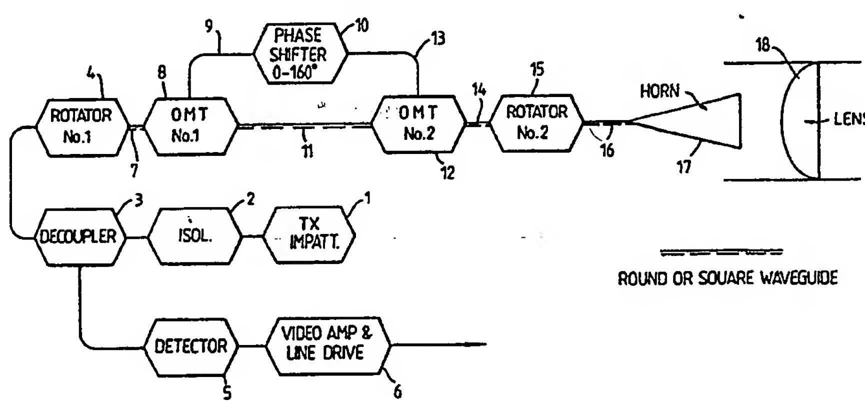
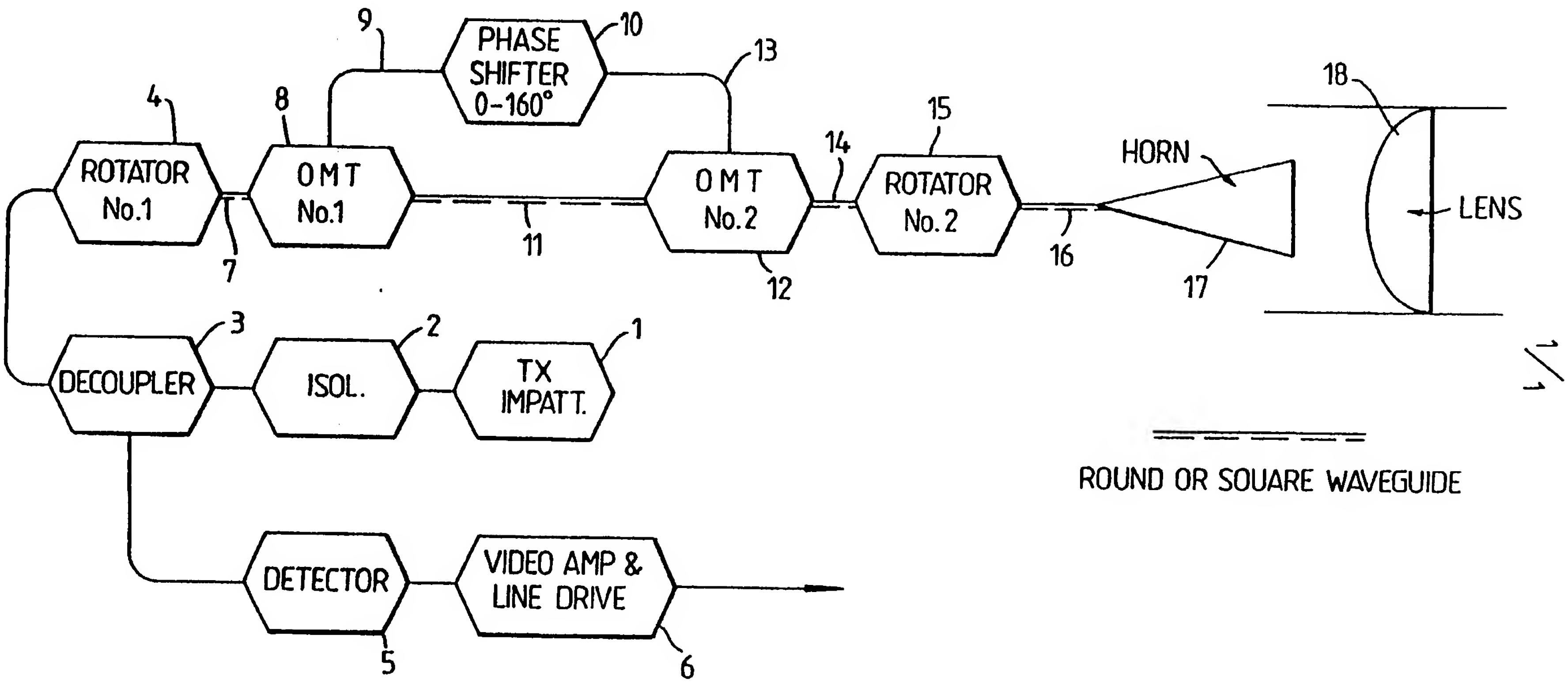
# (54) Polarisation controller for an antenna

(57) A polarisation controller for a radio frequency transmitter comprises a first polarisation rotator (4) having an input for coupling to the source 1, a polarisation resolver (8) coupled to an output of the first polarisation rotator (4) to resolve the output of the first rotator into components of two mutually perpendicular polarisations, a phase shifter (10) having an input coupled to one output of the polarisation resolver (8), a polarisation combiner (12) having inputs for waves of two mutually perpendicular polarisations one of which is coupled to an output of the phase shifter (10) and the other of which is coupled to the other output of the polarisation resolver (8), and a second polarisation rotator (15) having an input connected to the output of the polarisation combiner (12) and an output for coupling to an antenna (17).

In radio frequency transmitters there is a need to transmit radio frequency waves of predetermined polarisation. It is also desirable to be able to vary the transmitted polarisation state rapidly at will or in response to a feedback signal to, for example, improve subsequent reception of the transmitted signal.




GB 2 232 010 A


ROTATOR No.1
4
7
O M T No.1
8
9
PHASE SHIFTER 0-160°
10
11
13
O M T No.2
12
14
ROTATOR No.2
15
16
HORN
17
18
LENS
DECOUPLER
3
ISOL.
2
TX IMPATT.
1
DETECTOR
5
VIDEO AMP & LINE DRIVE
6
ROUND OR SQUARE WAVEGUIDE

# Transmitter Controller

In radio frequency transmitters there is a need to transmit radio frequency waves of predetermined polarisation. It is also desirable to be able to vary the transmitted polarisation state rapidly at will or in response to a feedback signal to, for example, improve subsequent reception of the transmitted signal.

As one example of this, radio frequency transmission especially at microwave frequencies are subject to fading as a result of scattering in the atmosphere. The atmospheric scattering is polarisation sensitive so that some polarisation states suffer a greater degree of scattering than others. It is therefore desirable to be able to vary the polarisation state of the transmitted signal with atmospheric changes to get the minimum scatter and hence the maximum signal transmission.

As another example in a radar transmission the polarisation of the transmitted radio frequency signal pulses is varied to be better able to discriminate the echo returned from a target from the background clutter. Varying the polarisation state of the transmitted radar signal also reduces the effect of multiple path reflection such as those from a low level target over the sea. By controlling the polarisation of the transmitted signal it is also possible to reduce the effects of electronic counter measures and to identify the nature of a particular target by analysing its return echo for transmissions of different polarisation state.

Conventional polarisation controllers are able to rotate the plane of polarisation of a plane polarised radio frequency transmission to provide a radio frequency transmission having its plane of polarisation at a predetermined orientation. One such system splits a

radio frequency signal from a source into two signals using a hybrid circuit and then imposes a phase change on one of the two signals by passing it through a first phase shifter. The output of the first phase shifter and the other signal from the hybrid circuit are then fed to two inputs of a second hybrid circuit. The outputs of the second hybrid circuit are fed through a variable power divider one output of which is fed to a second phase shifter. The output of the second phase shifter and the other output of the power divider circuit are fed to input ports of opposite polarisation state of an orthomode transducer. The two signals are combined in the orthomode transducer and fed to an antenna.

To vary the orientation of the plane of polarisation and to change from plane to circular and eliptical polarisation states the phase shifters are operated mechanically. Accordingly shifting between different polarisation states takes an appreciable amount of time so that it cannot, for example, be used to aid identification in radar system. Another difficulty is that each phase shifter imposes a large loss typically of at least 6 dB and hence the conventional polarisation controller imposes significant performance reduction on the transmitter.

According to this invention a polarisation controller for use in a radio frequency transmitter in which it is connected between a radio frequency source and an antenna capable of transmitting radio waves of any polarisation, comprises a first polarisation rotator having an input for coupling to the source, a polarisation resolver coupled to an output of the first polarisation rotator to resolve the output of the first rotator into components of two mutually perpendicular

polarisations, a phase shifter having an input coupled to one output of the polarisation resolver, a polarisation combiner having inputs for waves of two mutually perpendicular polarisations one of which is coupled to an output of the phase shifter and the other of which is coupled to the other output of the polarisation resolver, and a second polarisation rotator having an input connected to the output of the polarisation combiner and an output for coupling to the antenna.

Preferably there is a $\pi/2$ phase shift between the two paths between the polarisation resolver and the polarisation combiner and with this phase shift it is possible for the present invention to achieve all possible polarisation states from a plane polarised signal from the source.

The polarisation state of an electromagnetic wave can generally be described by a set of parameters which describe an ellipse. Conventionally it is considered that the electric vector of an electromagnetic wave traces out an ellipse in a fixed plane whose normal is collinear with the wavevector. The ellipse which is traced out by the tip of the electric vector can be traced out in either a clockwise or anticlockwise direction. When looking in the direction of propagation a clockwise rotation of the electric vector end point is called right-sense polarisation and anticlockwise rotation is called left-sense polarisation. There are other conventions in use which use the opposite definition of polarisation sense to the one described and used here. Elliptical polarisation can degenerate into two special cases: linear and circular polarisation states.

The parameters describing the elliptically polarised state are the axial ratio, tan $\tau$, which is the ratio of the semi-minor to semi-major axes of the ellipse and has

a range from $-1 \leq \tan\tau \leq 1$; and the orientation angle $\emptyset$, which gives the angle of the major axis with respect to the x - component of the electric field, where (x,y,z) is a right-handed reference frame, the wave propagates in the z-direction, and the sense of rotation of the electric vector is expressed by the sign of $\tau$, where a positive $\tau$ represents a right-handed sense and a negative $\tau$ represents a left-handed sense of polarisation.

The angles $\emptyset$ and $\tau$ are related to the amplitudes of the x- and y-field components $a_x$, $a_y$, and the phase difference between these components $\delta = \delta_x - \delta_y$, by the following equations:

$$\tan 2\emptyset = \frac{2a_x a_y \cos\delta}{a_x^2 - a_y^2}, \quad (1)$$

$$\sin 2\tau = \frac{2a_x a_y \sin\delta}{a_x^2 + a_y^2}, \quad (2)$$

The first polarisation rotator can select any orientation for the linear polarisation and couple this to the polarisation resolver which then resolves this linearly polarised mode in to two orthogonal linearly polarised modes, the x- and y-direction electric fields. The polarisation combiner recombines the x- and y-modes, with the x- and y- fields preserved and the second polarisation rotator acts upon these two orthogonal states and rotates both by an equal amount to any orientation. As the phase shifter is set so that an electrical path length difference between the two paths between the polarisation resolver and polarisation combiner is $\pi/2$ radians and assuming that the phase shifter is set so that the y component lags the x component by $\pi/2$ or 90°, then equations (1) and (2) this is equivalent to $\delta = +90°$.

Any linearly polarised state can be selected by adjusting the first polarisation rotator so that all the

signal goes through either the x path or all the signal goes through the y path and a single mode is fed to the second polarisation rotator. The second polarisation rotator then selects the orientation to produce any required linearly polarised state for transmission.

To select any right-handed sense of polarised wave the first polarisation rotator is used to obtain a linearly polarised wave with a plane of polarisation in the first and third quadrants. This ensures that the polarisation resolver resolves the incident wave in to two in-phase components x and y. The sense of polarisation is determined by the sign of sin $\delta$ and in the situation currently being described sin $\delta$ is positive, and therefore the sense of polarisation is right-handed.

To obtain a polarised wave which has a left-handed sense of rotation the first polarisation rotator selects a plane of polarisation in the second and fourth quadrants. Thus the polarisation resolver resolves the incident wave in to two anti-phase orthogonal x and y modes. The sense of rotation is now given by the negative of the sign of sin $\delta$, i.e. left-handed. The magnitudes of the x and y components is determined by the first polarisation rotator, and, therefore through equation (2) the axial ratio is specified. As the orientation angle of the elliptically polarised state is given by equation (1), and since cos $\delta = 0$ for $\delta = \pi/2$ then selection of the orientation angle, $\emptyset$ of any elliptically polarised wave is selected by the second polarisation rotator.

To obtain a circularly polarised state the first polarisation rotator rotates the linear polarised wave so that it is split into two equal components by the polarisation resolver.

Preferably the electrical path length of the two paths between the polarisation resolver and the polarisation combiner is substantially the same and the phase shifter imposes a phase shifter of $\pi/2$ radians.

This increases the bandwidth of the polarisation controller.

Preferably the first and second polarisation rotators are both formed by Faraday rotators which include a ferrite element and an electrical coil to impose a magnetic field upon the ferrite element and thereby control the degree of rotation imposed upon a radio frequency wave passing through the rotator.

Preferably the polarisation resolver and polarisation combiner are both formed by orthomode transducers having two separate input/output ports for radio waves of mutually perpendicular polarisation states and one input/output port for radio waves of any polarisation state.

The present invention also includes a radio frequency transmitter, a communication system, and a radar transmission system including a polarisation controller in accordance with this invention coupled between a source of plane polarised radio frequency waves and an antenna capable of transmitting radio frequency waves of any polarisation state.

When the source is a pulsed source of radio frequency waves and the transmitter is a radar transmitter, it is preferred that the switching speed of the first and second polarisation rotators is less than the pulse repetition frequency of the pulsed source to enable the polarisation state of the transmitted radar signal to be varied on a pulse-by-pulse basis. Such radar transmission systems may have a frequency of around 1 GHz and be used as surveillance radar, a very high frequency in a 75 to 95 GHz range and be used for short range high resolution radar such as that used with SMART munitions or have a mid frequency around 35 GHz, and be used as missile guidance and targeting radars.

When the transmitter transmits a continuous wave or

a phase coded wave and so is part of a communications system it typically transmits at 4.6 GHz, in the 12 to 14 GHz range or in the 20 to 30 GHz range. In all of these ranges atmospheric scattering occurs which is sensitive to the polarisation state of the transmitted signal and so the effects of the atmospheric scattering can be reduced by controlling the polarisation state of the transmitted signal. Preferably the transmitter includes an interactive system to set the polarisation state of the transmitted signal to that which produces the minimum atmospheric scattering. Such communication systems are frequently used for direct broadcast by satellite communications systems.

A particular example of a polarisation controller in accordance with this invertion will now be described with reference to the accompanying drawing which is a block diagram of an agile polarisation radar transmitter.

Radio frequency radiation is generated by a transmission impatt 1 (an impact avalanche transit time device) and fed via an isolator 2 and decoupler 3 to a first Faraday rotator 4. Another output from the decoupler 3 is fed to a detector 5 and video amplifier and line drive circuit 6 which is connected to a receive system for receiving a returned radar echo. The Faraday rotator 4 is connected via a waveguide 7 to a first orthomode transducer 8. The waveguide 7 is preferably a single mode, circular waveguide capable of supporting the circular $TE_{11}$ mode. Such a waveguide can support this mode irrespective of the orientation of its linearly polarised field distribution. The orthomode transducer resolves the output of the first Faraday rotator 4 into two components with mutually perpendicular polarisation states. The first component travels via waveguide 9 to a phase shifter 10 and the second component via a waveguide

11 to a first input of a second orthomode transducer 12. A further waveguide 13 connects the output of the phase shifter 10 to a second input of the second orthomode transducer 12. The output of the orthomode transducer 12 is connected via a waveguide 14 capable of supporting two orthogonal polarisation states to a second Faraday rotator 15 and the output of the Faraday rotator 15 is connected by a further waveguide 16 capable of supporting two orthogonal polarisation states to a scalar horn 17 which feeds a bloomed dielectric lens 18 to produce a directional, substantially collimated beam of radiation.

The orientation of the source 1, the first Faraday rotator 4 and the first orthomode transducer 8 is such that when the first Faraday rotator 4 imposes a zero rotation on a signal transmitted through it, substantially all of the radiation generated by the source 1 passes straight through the first orthomode transducer 8 and is fed directly to the second orthomode transducer 12 via the waveguide 11. This plane polarised signal is then fed to the second Faraday rotator 15 and the required orientation of the plane polarised radiation is controlled by the Faraday rotator 15 before it is fed to the horn 17 and lens 18 to provide a plane polarised output beam of predetermined polarisation orientation.

To produce an elliptically polarised output beam the first Faraday rotator 4 imposes some rotation to the plane polarised wave produced by the source 1 so that the first orthomode transducer 8 resolves this rotated beam into two plane polarised components having their planes of polarisation at 90° to one another. One component travels via the waveguide 11 whilst the other component travels via the waveguide 9 to the phase shifter 10. A phase shifter 10 imposes a $\pi/2$ phase shift to the signal and then this is fed to the second input of the second

orthomode transducer via the waveguide 13. The two components, the phase of one of which has been shifted by the phase shifter 10 are combined in the second orthomode transducer 12 to produce an elliptically polarised wave which is fed via the waveguide 14 to the second Faraday rotator 15. The degree of rotation imposed by the second Faraday rotator 15 controls the orientation of the major axis of the elliptically polarised wave before it is fed to the horn 17 and lens 18 to provide the elliptically polarised output beam. Rotation of the beam by the rotator 4 into the first and third quadrants results in a right handed elliptical polarisation state and rotation in the second and fourth quandrants results in a left-handed elliptical polarisation.

A circularly polarised output beam is a special case of an elliptically polarised beam and, in this case, the rotation imposed by the first Faraday rotator 4 is such as to rotate the plane of polarisation of the signal produced from the source 1 so that it is at ±45° to the plane of polarisation of both outputs of the first orthomode transducer 8. In this way an equal signal is fed via the waveguides 9 and 11 and, in turn, equal signals fed to the inputs of the second orthomode transducer 12 which results in a wave of circular polarisation state. It may be necessary to vary the ± 45° orientation imposed by the first Faraday rotator 4 to compensate for any imbalance in the loss imposed by the different paths.

The degree of rotational change imposed by the Faraday rotators 4 and 15 can be changed very rapidly via the application of a predetermined electrical current to a magnetising coil of each rotator 4 and 15. Accordingly, it is possible to change the polarisation state of successive pulses generated by the source 1 when the system is operating at its typical pulse repetition frequency of 50 KHz.

CLAIMS

1. A polarisation controller for use in a radio frequency transmitter in which it is connected between a radio frequency source and an antenna capable of transmitting radio waves of any polarisation, comprising a first polarisation rotator having an input for coupling to the source, a polarisation resolver coupled to an output of the first polarisation rotator to resolve the output of the first rotator into components of two mutually perpendicular polarisations, a phase shifter having an input coupled to one output of the polarisation resolver, a polarisation combiner having inputs for waves of two mutually perpendicular polarisations one of which is coupled to an output of the phase shifter and the other of which is coupled to the other output of the polarisation resolver, and a second polarisation rotator having an input connected to the output of the polarisation combiner and an output for coupling to the antenna.

2. A polarisation controller according to claim 1, in which there is a $\pi/2$ phase shift between the two paths between the polarisation resolver and the polarisation combiner.

3. A polarisation controller according to claim 1 or 2, in which the electrical path length of the two paths between the polarisation resolver and the polarisation combiner is substantially the same and the phase shifter imposes a phase shifter of $\pi/2$ radians.

4. A polarisation controller according to any one of the preceding claims, in which the first and second polarisation rotators are both formed by Faraday rotators which include a ferrite element and an electrical coil to impose a magnetic field upon the ferrite element and

thereby control the degree of rotation imposed upon a radio frequency wave passing through the rotator.

5. A polarisation controller according to any one of the preceding claims, in which the polarisation resolver and polarisation combiner are both formed by orthomode transducers having two separate input/output ports for radio waves of mutually perpendicular polarisation states and one input/output port for radio waves of any polarisation state.

6. A polarisation controller substantially as described with reference to the accompanying drawings.

7. A radio frequency transmitter, a communication system, or a radar transmission system including a polarisation controller in accordance with any one of the preceding claims coupled between a source of plane polarised radio frequency waves and an antenna capable of transmitting radio frequency waves of any polarisation state.

8. A radar transmission system according to claim 8, in which the switching speed of the first and second polarisation rotators is less than the pulse repetition frequency of a pulsed source of radio waves to enable the polarisation state of the transmitted radar signal to be varied on a pulse-by-pulse basis.

9. A radio frequency transmitter or a communication system according to claim 7, in which the transmitter transmits a continuous wave or a phase coded wave.

10. A transmitter or system according to claim 9, in which the transmitter includes an interactive system to set the polarisation state of the transmitted signal to that which produces the minimum atmospheric scattering.

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